KING COUNTY CONVEYANCE SYSTEM IMPROVEMENT PROJECT

CONVEYANCE SYSTEM COST SYSTEM TUNNEL COST PARAMETERS

FINAL REPORT

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in association with

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and

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INTRODUCTION

The purpose of this memo (originally written in 1999) is to define the parameters and unit costs used to the cost model for various tunneling technology alternatives. This memo includes specifics on the structure of the tunnel cost module. The tunnels outlined in this memorandum include only tunnels 6-foot in diameter and greater that permit manned tunnel boring machines (TBMs). Other trenchless tunneling construction techniques such as microtunneling and horizontal directional drilling are discussed in another memorandum. A more general discussion of the purpose of the model is included in the September 2001 *Conveyance System Cost Estimates – Task 250 Report.*

TUNNEL COST MODEL

The model will be structured to provide the user with a formatted means of data entry and a formatted output for incorporation into other cost estimating models. The relationship between the scope of this work and other cost models is detailed in the Figure 1.

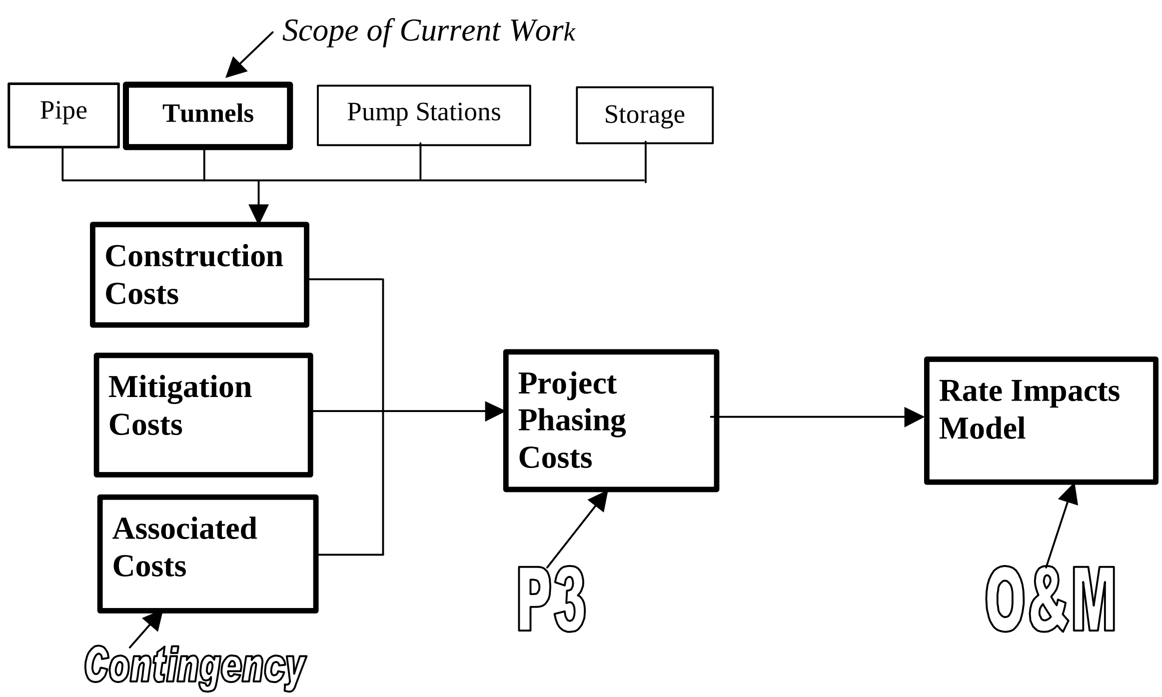

Figure 1. Cost Development Relationships

TUNNEL COST MODULE

The construction costs of tunnels are influenced by a number of factors including the size of the tunnel, soil conditions, length of the drive, dewatering concerns, and the depth of the portals, especially the launch portal. These parameters and other factors were incorporated into this model component, providing user flexibility to adjust for site-specific conditions and design criteria that will likely be known at the planning level. All of the costs include contractor overhead and profit and are based on the cost estimates and bid prices for recent tunneling projects.

Fixed Model Parameters

Fixed parameters are imbedded in the model and are not modified by the user. These fixed parameters reflect unit prices for the base model month and year as shown on the introduction screen. The model caretaker can only modify them with password access. This would typically be done as part of adjusting the model cost base month and year and adjusting the ENR Seattle CCI. Otherwise, these imbedded costs are not expected to vary significantly between projects. Table 1 lists those cost items with imbedded unit costs or percentage used in the initial model.

Table 1. Fixed Input Parameters

Items	Units	Assumption/Unit Cost[1]
Shaft Excavation, Backfill, and Haul	CY	$9
Asphalt Pavement	SY	$50
Existing Utilities (Average)	SF	$6
Existing Utilities (Complex)	SF	$10
Hydroseed	SY	$5

Notes:
(1) Based on ENR Seattle CCI = 7,137 for December 1999.

A watertight shoring system was assumed for all of the launch and retrieval shafts. The cost for shoring increases with the depth of the shaft. This increase was assumed to be linear and is identified by the equation:

$$\text{Cost (\$/sf)} = \$1.60/\text{ft} \times \text{Depth (ft)} + \$9$$

Based on this equation, the cost for shoring will increase with depth on a per square foot basis as outlined in Table 2.

Table 2. Shoring Costs

Shoring Depth (feet)	Cost[1] ($/sf)
20	41
40	73
60	105

Notes:
(1) Based on ENR Seattle CCI = 7,137 for December 1999.

User Input Parameters

The model is configured to allow for a variety of site conditions by adjusting certain input parameters. These project specific input parameters and the default values are summarized in Table 3. In some cases, there will be construction costs that are unique to a given project. These costs may include special landscaping requirements, artwork, unique street improvements, and other miscellaneous construction costs. To account for these costs at the planning stage, the user will be allowed to input a fixed dollar amount that will be calculated separately by the user with a box for noting what the additional costs include.

Table 3. Project Specific Input Parameters

Parameter	Options	Default
Project Name	User must input project name	Must be input by user
Construction Year	User may select future construction year	Current Year
Tunnel Inside Diameter	8-20 feet	Must be input by user
Tunnel Length	User must input	Must be input by user
Launch Shaft Footprint	Standard; Oversized	Standard
Dewatering for Shafts	None; Minimal; Significant	Minimal
Launch Shaft Utilities	None; Average Complex	Average
Launch Shaft Excavation Depth	User must input number greater than 15 feet	40
Launch Shaft Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Retrieval Shaft Excavation Depth	User must input number greater than 10 feet	20
Retrieval Shaft Surface Restoration	None; Hydroseed, Pavement	Hydroseed
Unique Construction Costs	User must input a cost number	0
Total Length of Tunnel Easements	User defined length	0
Type of Tunnel Easements	None; Residential; Industrial; Commercial	0

Launch Shaft Characteristics

The cost of the launch shaft will primarily vary with the footprint, depth, and dewatering for the site. Surface restoration requirements and other site-specific factors may also significantly affect the launch shaft cost. The standard launch shaft footprint was developed based on a review of several tunnel launch shafts. In general, the launch shaft should be large enough to include the space for two parallel tracks and a switch for the muck cars. Based on a review of several launch shafts and this parameter, the standard launch shaft footprint is approximately three time as wide as the tunnel outside diameter (OD) and 9.5 times as long as the tunnel OD. The unit costs identified in Table 1 will be used by the model to estimate the surface restoration and excavation costs for the launch shaft.

Tunnel Characteristics

The tunnel cost will vary based on the tunnel diameter and geotechnical conditions. There are also significant mobilization and demobilization costs associated with a tunneling project, primarily associated with procurement and delivery of the tunnel boring machine (TBM). These initial costs will make shorter tunnels appear more expensive than longer tunnels when compared on a per-lineal-foot of tunnel basis. For this reason, these mobilization costs are tabulated separately from the tunneling costs (Table 4).

Table 4. Tunnel Dimensions and Costs

Tunnel Inside Dia (ft)	Tunnel Outside Dia (ft)	TBM Procurement[1] (Lump Sum)	Tunnel Cost[1] ($/lf)
8	9.25	$1,500,000	$2,000
9	10.25	$1,800,000	$1,950
10	11.33	$2,000,000	$1,950
11	12.33	$2,300,000	$2,000
12	13.33	$2,500,000	$2,200
13	14.33	$2,700,000	$2,400
14	15.50	$3,000,000	$2,500
15	16.50	$3,300,000	$2,700
16	17.50	$3,600,000	$2,900
18	19.50	$4,000,000	$3,100

Notes:
(1) Based on ENR Seattle CCI = 7,137 for December 1999.

The user may be interested in the quantity of spoils and the number of truck hauls for a given tunneling project. For this reason, the output from the tunneling project will include the total quantity of spoils generated and the number of truck trips required based on a 10 CY of dirt per truck haul.

Retrieval Shaft Characteristics

Similar to the launch shaft, the cost of the retrieval shaft will primarily vary with the footprint, depth, and dewatering for the site. Surface restoration requirements and other site-specific factors may also significantly affect the retrieval shaft cost. In general, the retrieval shaft only needs to be large enough to accommodate the removal of the TBM. Based on a review of several retrieval shafts, the standard retrieval shaft footprint is approximately 2.5 times as wide as the tunnel outside diameter and 3.5 times as long as the tunnel OD. The user has the option of using these standard parameters or overriding the standard parameters with a user input value. The unit costs identified in Table 1 will be used to estimate the cost for the retrieval shaft.

Right of Way

It is anticipated that tunnels will be constructed, to the maximum extent practical, in existing right-of-way. In some cases tunneling easements will be required. In some cases, property acquisition may be required. The costs for easements and acquisitions were developed from previous County projects. These easement and acquisition costs are summarized in Table 5. To calculate the width of the tunneling easements, it was assumed that the permanent tunneling easement width would be equal to the tunnel OD plus 20 feet. Another simple way to estimate the cost of property acquisition and tunneling easements at the planning stage would be to obtain the information for the parcels transected by the proposed tunnel alignment from the King County Assessor's Office.

Table 5. Right-of-Way Acquisition and Easement Costs

Area	Property Acquisition Cost[1] ($/sf)	Tunneling Easements[1,2] ($/sf)
Residential	$22	$7
Industrial	$10	$3
Commercial	$20	$6

Notes:
(1) Based on ENR Seattle CCI = 7,137 for December 1999.
(2) Acquisition and easement costs are based on a memo from William Wilbert to Ed Cox RE: Value Estimates for Property Types.

Dewatering

In most cases, dewatering will be minimal since watertight shoring systems and watertight seals or tremie slabs will be used for the microtunnel access shafts shafts. Nonetheless, some dewatering will be required. Table 6 summarizes these dewatering costs for a given length project. In reality, the dewatering cost will include some initial costs plus additional costs to maintain the system for the duration that the launch and retrieval shafts are open. The tunnel length was used as a surrogate to estimate the duration that the dewatering systems will need to function at an estimated cost of $350 per day.

Table 6. Dewatering Costs

Tunnel Length (ft)	Standard Dewatering[1] (Total $)	Significant Dewatering[1] (Total $)
<1,000	$40,000	$60,000
1,000-5,000	$45,000	$70,000
5,000-10,000	$50,000	$90,000
>10,000	$60,000	$100,000

Notes:
(1) Based on ENR Seattle CCI = 7,137 for December 1999.

Outputs

The output from the model will summarize the input parameters and model outputs in a spreadsheet format that can be exported into other King County cost model component.